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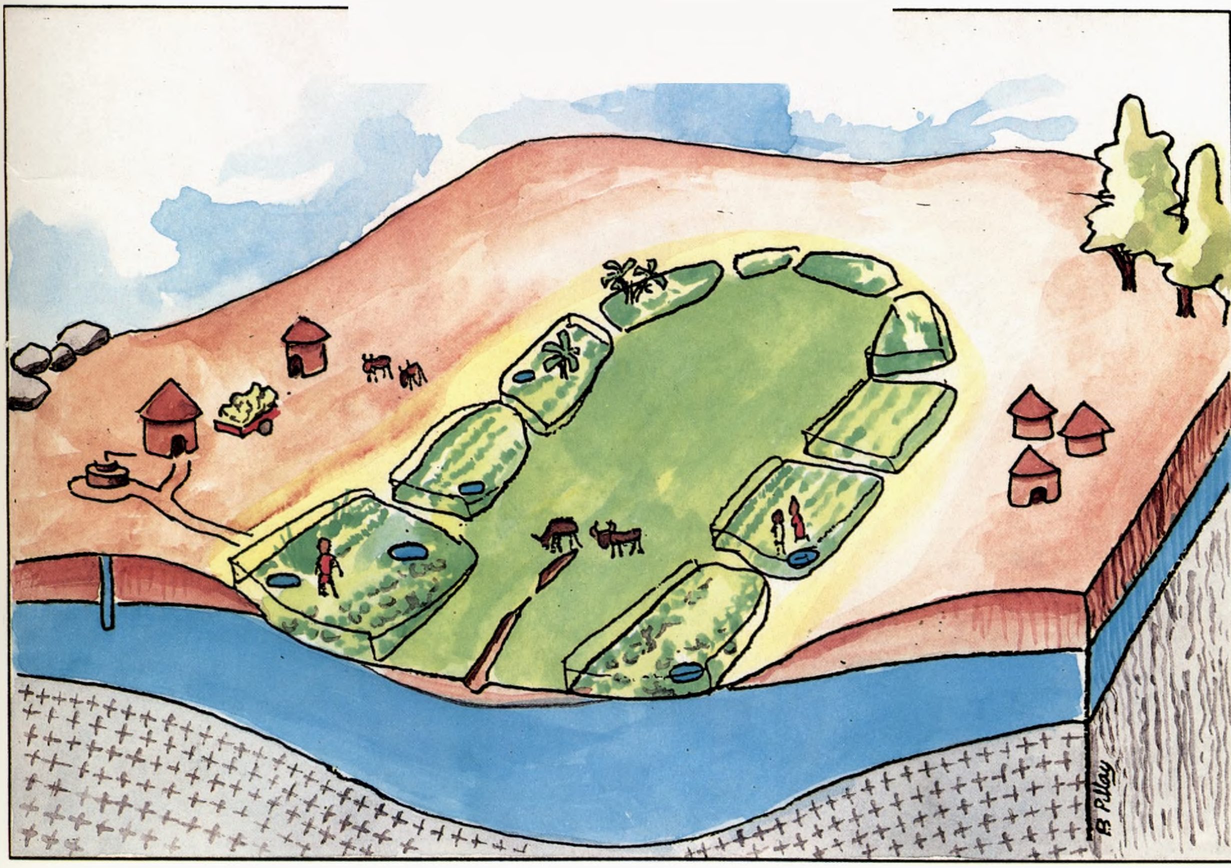

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Editors: Richard Owen, Katherine Verbeek, John Jackson and Tammo Steenhuis

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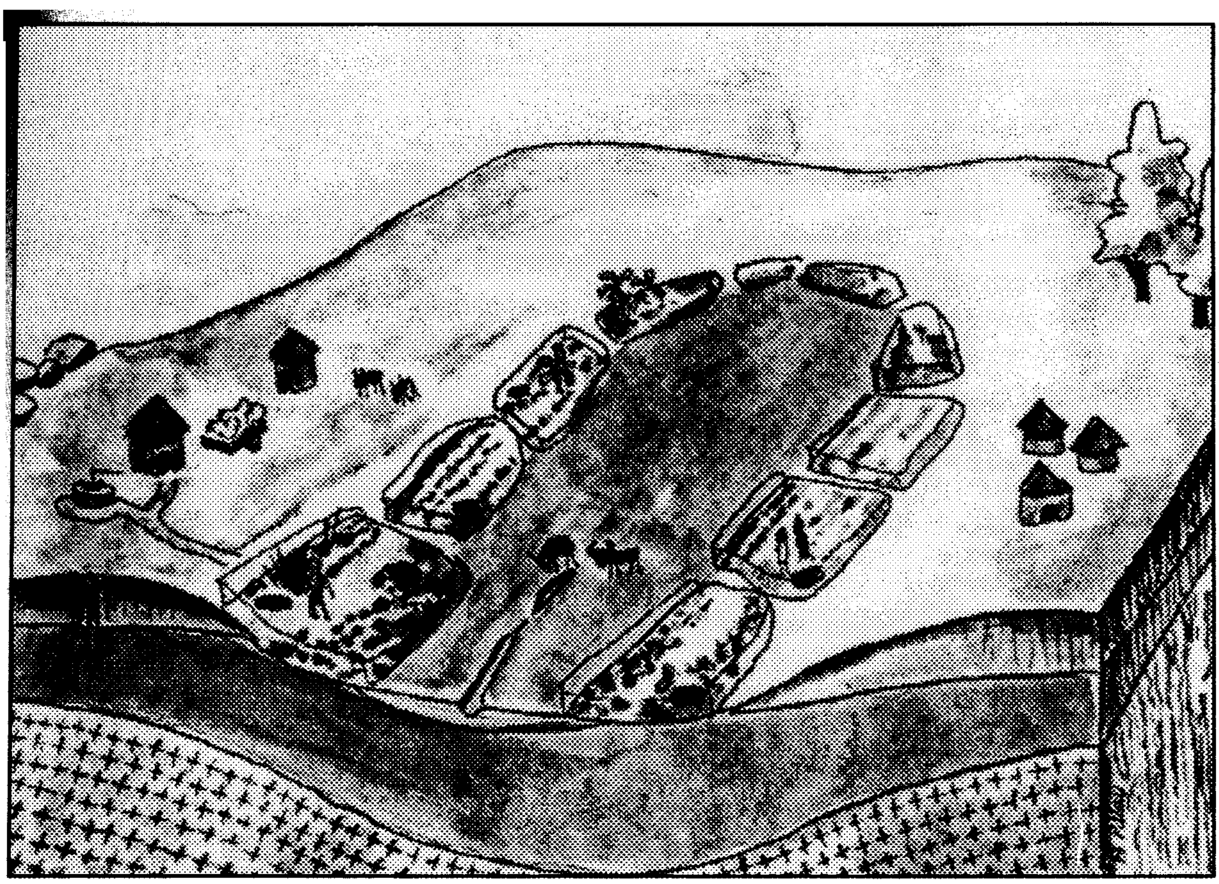
Section I

Water Management



The Smallholder Farm as an Appropriate Water Management Unit in Wetland Development

N. C. van de Giesen and T. S. Steenhuis[1]

Introduction

Rising population pressures in Africa have caused the agricultural use of wetlands to become increasingly important. Developing large surface irrigation infrastructures, as Asia did during the sixties and seventies, often proves to be too costly for Africa. This makes wetlands, with their relatively good water availability and high soil fertility, an interesting alternative for increasing food production. Wetland use offers economic advantages as well. Farming on wetlands is a labor-intensive process, while surface irrigation is capital-intensive.

African wetlands show a wide variety in size, climate, and history. There are the vast internal deltas of the Nile, Congo, and Niger Rivers, as well as the very small bas-fonds of the Sahel and the dambos of Southern Africa. In East Africa, one can find upland valleys in a monsoon climate and poorly drained areas in arid regions. Some wetlands have been used for agriculture for centuries, like the Okavango and the Mangroves of West Africa, and others have just recently drawn the attention of farmers who traditionally grow upland crops. Most wetlands, however, have received a fairly recent interest from government and foreign agencies. This interest involves both intensification of traditional practices and the reclamation of previously unused wetlands.

There is not only variety among wetlands but also within them. One of the main characteristics of wetlands is a large variability in soils and water regimes. Wetland soils are very susceptible to changes in groundwater levels. Over-drainage of wetland soils may cause irreversible drying, loss of organic matter and fertility, and acidification. Variability and sensitivity are major obstacles for large scale development projects. Although larger infrastructural improvements, such as providing a drainage outlet and flood protection, do have their place, such improvements should allow flexibility at the farm level. Government and donor agencies should be aware of the negative

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side effects that indiscriminate large scale interventions can have.

The farm is the level at which the variabilities of the land can be dealt with most effectively. Farmers have two effective techniques to accommodate diverse soil conditions and various water regimes: using appropriately sized raised beds and selecting optimal crop types and cultivars.

Two cases from Guinea-Bissau and Rwanda, illustrate how farmers use these techniques to overcome a range of problems. The case from Guinea-Bissau concerns a very old system of mangrove rice cultivation. Problems facing the farmers here include flooding, lack of fresh water, salt intrusion, and highly acidic soils. The case from Rwanda describes the present use of the wet upland valleys (marais). Over the last 40 years, these valleys have been taken into agricultural use in response to increasing population pressures. The cropping pattern consists mainly of sorghum in the wet season and sweet potatoes in the dry season. Problems in Rwanda are flooding and poor soil fertility reflected in a low pH, and water shortages in the dry season.

The problems in the two cases are completely different, yet the farmers have been able to overcome them in a sustainable way, mainly by using raised beds and choosing the appropriate crops and varieties. Unfortunately, there are examples in both cases in which large scale interventions have caused irreparable damage. The interventions were aimed only at preventing flooding which is only one of the factors that limits production. Although they succeeded in removing the excess water, they also lowered the groundwater table too deeply. In Rwanda, this led to yield reduction and in Guinea-Bissau, to an annihilation of production.

Mangrove Rice in Guinea-Bissau[2]

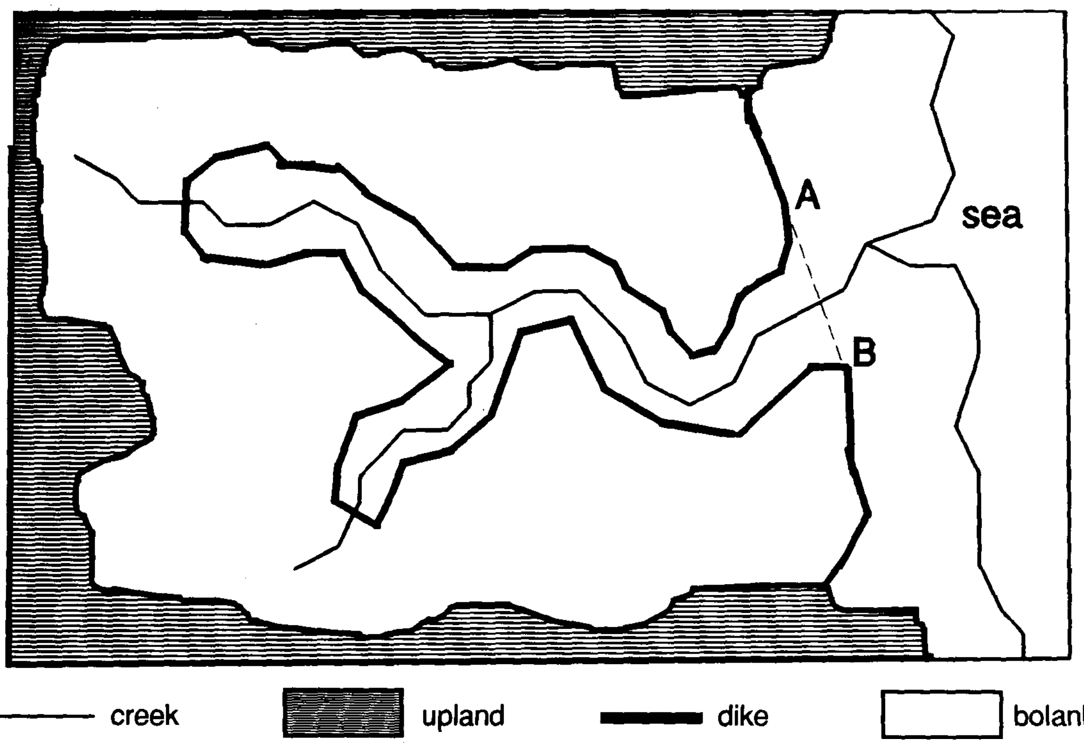
The West African coast, from Gambia to Liberia, is lined with mangrove swamps. Throughout this ecosystem, a specific type of rice culture is found. In Guinea-Bissau, this type of agriculture is the main subsistence source for the Balanta tribe. Over the centuries, the Balantas have developed a sophisticated rice farming system. The mangrove areas are reclaimed by building a dike along a creek, preventing periodic flooding (see Figure 1). After the dike is closed, the mangrove trees are removed from the new polder or bolanha.

Typically, a household owns different fields in the bolanha on which they grow rice. They encounter such problems as salinity, flooding and water. The most severe constraint is high acidity. Mangrove soils often contain pyrite. When these soils are drained, the pyrite is oxidized, leading to the formation of sulfuric acid. Very low pH values (<2.5) have been observed. To counter these various constraints, farmers use techniques such as ridges and careful selection of cultivars.

In most places, wet rice is grown on carefully equalized fields. In Guinea-Bissau, however, rice is grown on ridges which still allow the rice crop to form a closed canopy when it enters the flowering stage. The height of the ridges varies between 0.25 and 1.5 m. The ridges are reconstructed each year such that the old furrow becomes the new ridge and vice versa. Construction of the ridges is very labor-intensive and the preparation of the fields accounts for the yearly peak in labor demand. Ridges are made with a special spade, called an *arrado*, which consists of a long (70 cm) wooden blade with a sharp iron edge and a very long (3 m) handle. The *arrado* is inserted in the old ridge under a small angle, cutting off a long and thin slice of clay. The slices are piled up in a roof tile fashion which facilitates the lateral drainage of the ridges. The grassy top layer of the old ridge is deposited at the bottom of the furrow, causing a discontinuity

[2]Material for this case was gathered during a five month field study in Guiné-Bissau in the Bissassema Rural Engineering Project (see LUW, 1986; van de Giesen, 1985).

• I. Typical reclamation of mangrove areas



in the capillaries, which hinders the rise of the deeper and more saline groundwater. In the lower areas, the ridges primarily serve a water management function: they prevent the flooding of the rice plants. It is in these wetter areas that the higher ridges can be found. In the drier parts, the ridges are constructed for soil management purposes. During the dry season, acidity and salinity levels rise in the topsoil. The first rains easily wash out salts and acids from the laterally draining ridges. This process would be impossible in a flat field.

The problems encountered in mangrove rice culture often show great variability over short distances. This is especially true for acidic soils, which can be quite sparse. The use of differently sized ridges helps to overcome these problems to a certain extent, but the use of different cultivars seems to be even more important in this case. Every subsistence agriculturalist naturally selects the more productive seeds because there will simply be more of those in the harvests.

The Balantas, however, are very conscious about selecting the best seeds. From every field, the highest yielding rice panicles are selected and their seeds are kept separate from the rice which is to be consumed. To say that every field has its own optimal cultivar would hardly be an overstatement. The importance which is given to the seeds is exemplified by the fact that farmers are known to walk over a hundred miles to obtain a

To say that every field has its own optimal cultivar would hardly be an overstatement. The importance which is given to the seeds is exemplified by the fact that farmers are known to walk over a hundred miles to obtain a certain promising variety.

certain promising variety. It is also, therefore, no surprise that ROC5 (the West African version of the famous IR5) could be found throughout Guinea-Bissau shortly after its introduction, even though it was not accompanied by any extension effort.

The differently sized ridges and the dynamic use of the broad genetic base of rice suggest that there would be little room left for improvement. Guinea-Bissau, however, was strongly affected by a long and bloody independence war against the Portuguese. Villages were depopulated, dikes bombed and families separated. After independence in 1972, the bolanha production was very low. Foreign aid was aimed at rebuilding the country and a special effort was put into revitalizing the bolanhas. It became clear that the social disruption made it very difficult to rebuild and maintain the dikes in the traditional way, and large clay-filled laterite dams were built to seal off large creeks (connecting points A and B in Figure 1). This protected the bolanhas from salt water intrusion and, at the same time, strongly reduced maintenance requirements. Instead of a long vulnerable dike following the creek, there was now a short solid dam.

Although the objective of protecting the bolanhas from the sea was achieved, the dams had some unforseen consequences. Before the creeks were dammed, the sea water entered twice daily, maintaining the groundwater level slightly above the average water level in the creeks. Any available fresh water floats on top of saline groundwater from the creeks, minimizing the capillary rise of salts.

As a consequence of building a dam across the inlet of the creek, the groundwater levels decreased drastically during the dry season (up to two meters). The pyrite in the soil profile oxidized and formed sulfuric acid. The pH in many of the fields became so low that they were unsuitable for the growing of rice and had to be abandoned.

The large scale interventions did not take into account the effects that a dramatic lowering of the water table can have on soil properties. The dams caused a much larger drop in the groundwater level than would have been caused by the traditional dikes. Moreover, the whole area behind the dam was affected, which made it impossible to wash out the acids with the aid of ridges.

Marais Agriculture in Rwanda[3]

Agriculture in Rwanda traditionally takes place on the hills. Rwanda is the most densely populated country in Africa (751 people per square mile) and the population is still increasing. Over the past fifty years, farmers have reclaimed the wet valleys (marais) between the hills. Earlier use of the marais was limited to grazing, but their importance for crop production has grown steadily over the past decades. Covering 10% of cultivated land, they provide an estimated 20% of the agricultural output, yielding two harvests per year in contrast to the one annual harvest on the hills. The marais have also become an integrated part of the total production system by providing the hills with cuttings for the vegetatively reproduced sweet potatoes at the beginning of the wet season.

The Nyamigogo marais, which is highlighted here, was one of the first marais to be reclaimed. The reclamation of this marais was started under, and instigated by, Belgian colonial rule in 1942 and was completed just before independence in 1960. The reclamation of the Nyamigogo was a consequence of a major drought and famine in the 1930s. The plan was to grow sweet potatoes in the marais as food security for times of drought. Sweet potatoes are very well adapted to sub-optimal conditions. They are relatively immune to water shortages and give a reasonable yield, even when nitrogen and phosphorus levels are extremely low. The drawback is that they have a long growing season of six to eight months.

Currently, the two main crops grown are sweet potatoes and sorghum. Sweet potatoes

[3]The material for this case was collected during a 12 month PhD field study in the Nyamigogo Marais Pilote in Rwanda (see also Sikkens and Steenhuis, 1988).

are grown during the dry season throughout the marais and, in the wet season, only in the driest parts of the marais. In the wet season, sorghum is the main crop.

Sorghum is usually associated with areas which are too dry to grow corn, but the same vigorous root growth which makes it suitable for dry areas also makes it suitable for areas with periodically high water tables. When the groundwater rises for three or more days, roots which are submerged will begin to die off. Because the root growth capacity of sorghum is very high, the roots will grow back without very much damage to the crop when the water drops again. This only holds true when the plants have not yet reached the reproductive stage. The farmers sow sorghum at such a time that the flowering stage coincides with the end of the rainy season. One sees, therefore, only a very small spread in growth stages in sorghum, as opposed to that for sweet potatoes which are planted over a period of several months.

In Guinea-Bissau, the ridges were used as a means to adjust to the soil and water conditions and the different cultivars were used for the fine tuning the agricultural production process. In Rwanda, it is the other way around. The crop choice is used to adjust to the more general water conditions, whereas, the beds are used to adopt to the small scale variations. Not only do the beds facilitate drainage, but they also make sub-surface irrigation possible in the dry season. Both dimensions and orientation of the beds are chosen in such a way that they fit the water regimes. The width of the beds varies between 1.5 and 5 m. In the depressions and at confluents, there are narrow and high beds with large ditches parallel to the stream direction. In the drier parts, the beds are relatively flat, the ditches are small and they are oriented perpendicular to the main drain. Sorghum is grown on beds which are flatter than the beds which are constructed for the growing of sweet potatoes.

The beds are reconstructed at the beginning of every growing season. The entire bed is worked over to a depth of 0.5 - 1 m . This is a labor-intensive process because the amount of displaced earth is about three times of what is needed for the preparation of a field on the hills. The top 50 - 70 cm are placed at the bottom of the new bed. The burying of this layer, which contains the roots and seeds of the weeds, ensures that the new seedlings can grow without competition. Next follows a layer of muck from the ditches, which is covered with a layer of dry soil.

The incorporation of the soil and plants from the ditch is very important for maintaining the soil fertility. Nitrogen is fixed in the anaerobic ditches while, at the same time, the lack of oxygen prevents a quick decay of dead plants. Water plants are low in fiber, which makes them a good green manure and there is no risk that they will overgrow the crop. The wide ditches, which sometimes even exceed the width of the beds, seem, to many outsiders, to be a complete waste of land. The ditches play an important role in providing organic matter and regulating the water supply.

A technical intervention by foreign donors between 1970 and 1972 was aimed at improving the water management of the Nyamigogo marais, but did not take the advantages of a high water table into account. The intervention consisted of the enlargement of the central drain and the construction of irrigation canals along the hills. The irrigation system was not backed up by the formation of farmer organizations to handle operation and maintenance of the canals failed in the first year.

The new central drain was very deep, at some places 2 m below field level. In contrast to most wetlands, the Rwandan marais have a strong slope of 1 - 2%. This means that the canal is able to accommodate very high discharges. It also means that the water levels in the dry season drop to just some centimeters above the canal bottom. When this is not compensated by a surface irrigation system, it is clear that these low groundwater levels will cause water shortages in the root zone during the dry season. In a recent survey, 26% of the farmers mentioned water shortage as the most important production problem (Centre de Services aux Cooperatives, 1991). If the marais had been in use for centuries, the farmers

The suggested restrained-engineering approach, which does not seek to prevent every possible drainage problem but acknowledges the technical capacity which exists at the farm level, will help to prevent long-term wetland degradation.

would probably have countered the lower water levels with checks in the canal. But because the marais has been developed relatively recently, no such organized action was undertaken.

The farmers said that the harvests in the marais had been impressive from the reclamation until the 1970 intervention. One always has to be careful with this type of information, because most farmers will usually say that food was abundant in the past. However, the fact that this information was given without any prompting and that it was so exactly dated lends it credibility. The water shortages are a clear cause for the reduction of the dry season harvests. Wet season harvests were probably reduced by the loss of organic matter which resulted from lower water levels. Organic matter will not only oxidize faster in a dry soil, but there will also be no accumulation of new material when the ditches are dry. It is very apparent that, at those places where the bottom of the main drain lies deep below the surface, the organic content of the soils is much lower than in those places with a shallow canal.

Again, we see the negative side effects of large scale intervention. The intervention was aimed at removing excess water. No attention was given to the positive influence a higher water table has during the dry season. The present pilot project in the Nyamigogo marais can easily reverse the water shortages, but the degradation of the soil is permanent.

Considerations for the Design of Wetland Improvements

The depth of the groundwater is probably the single most important soil-forming factor in natural wetlands. Changing the groundwater depth inevitably changes soil properties. The exact effects are not always easy to predict and are often overlooked by engineers. However, in order to bring wetlands into production, the natural water level needs to be adjusted. The question is how to approach this problem.

A first consideration is the variability of soil conditions and water regimes over short distances. Adopting one criterion for the whole wetland will often mean that most places will be either too dry or too wet. The design should incorporate the flexibility which exists at the farm or field for dealing with different water levels. This means, for example, that a small depression should not become the standard for the maximum water level in the whole wetland.

Another implication for the design of wetland improvements is that excess water is not the only water management issue and that over-drainage during the dry season should be avoided. The standard drainage design procedure is to calculate the canal dimension so that it is overtopped not more than once every five or ten years. This means that the canals are over-designed for most of the time during the year. This became very apparent in Rwanda, where the large slopes enabled the engineers to construct high capacity canals that desiccated the marais in a short time.

Over-designing a drainage system for agriculture in the humid regions of Western Europe does not usually lead to insurmountable problems. The changed chemical properties of the soils can often be remedied by lime, fertilizers, and pesticides. A water shortage during the summer can be controlled with movable sprinklers. In Africa, these solutions are not available to the farmers, and a different approach should be used. Presently, drainage in Western European countries is usually prompted by trafficability problems in spring and fall and not by considerations about direct damage to the crop. For most African countries, trafficability for heavy machines is not a concern and only crop damage should be taken into consideration. Occasional high water tables do not always cause major yield reductions. The drainage criteria for African agriculture can, therefore, be lower than for mechanized agriculture.

The drainage reclamation projects from the two cases presented here led to draining or diking out too much water. This happens in many other wetland improvement projects in climates with distinct wet and dry seasons. The cases show that this may lead to permanent degradation of the soil. At the same time, the benefits of a low water table are questionable, whereas the farmers are very capable of managing high water tables with the aid of raised beds and choosing the right crops. It is almost impossible for a large scale infrastructural improvement to address the enormous variability in soil and water regimes. It is, therefore, suggested that the design be based on a conservative estimate of maximum *and* minimum water tables to avoid negative side effects. In this context, conservative means on the wet side, rather than on the dry side.

The suggested restrained-engineering approach, which does not seek to prevent every possible drainage problem but acknowledges the technical capacity which exists at the farm level, will help to prevent long-term wetland degradation.

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